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iMAST

Institute for Manufacturing and Sustainment Technologies

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY

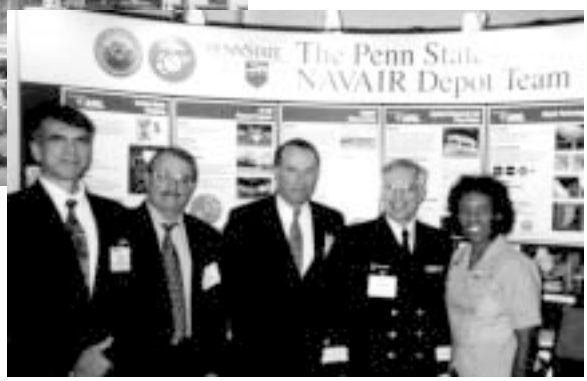
1999 No.4

Transforming Maintenance with Technology and Smart Logistics: The iMAST-NAVAIR Depot Team

In support of its Repair Technology (RepTech) effort at ARL Penn State, iMAST recently joined with NAVAIR to participate in the 3rd Annual DoD Maintenance Symposium & Exhibition held in St. Louis, Missouri.

Sponsored by the National Defense Industrial Association, in conjunction with the Office of the Secretary of Defense, the maintenance conference reflects the increasingly integrated nature of maintenance and logistics partnered support between the public and private sectors. The DoD currently expends $40 billion a year on maintenance-related activities within its logistics effort. The symposium focused on DoD weapon systems and equipment maintenance. Symposium sessions were designed to relate maintenance challenges to emerging technologies that will transform maintenance operations in the future. This theme is a timely one: military services are currently working to leverage advanced technical capabilities to more efficiently execute their maintenance responsibilities. Maintenance systems for the future will be driven by operational requirements and will be even more integrated with other logistics disciplines, will rely increasingly on commercial support, and will be more responsive yet less costly.

FOCUS ON REPAIR TECHNOLOGIES



RIGHT (Center) (L-R) NADEP Cherry Point engineers Bob King and Gray Simpson join ARL's Lewis Watt, Rear Admiral Stephen C. Heilman, USN, and Colonel Gilda Jackson, USMC. RAdm Heilman is the Asst. Commander for Industrial Capabilities at NAVAIR (AIR 6.0).

Captain Coleen Watry, USN, C.O. of the Naval Aviation Depot at NAS North Island, and Colonel Gilda Jackson, Executive Officer of the Naval Aviation Depot at MCAS Cherry Point, pause for photo with Lewis Watt, Deputy Director, iMAST.

iMAST and NAVAIR teamed to provide information on the RepTech Program and the value-added effort it brings to the Fleet today. Mr. Lewis Watt, deputy director of ARL Penn State's Navy ManTech Center of Excellence, provided lectures on the subjects of Laser Cladding and Reverse Engineering of Test Requirements and Support Equipments, during Depot Maintenance Technologies breakout sessions. ARL research associate Bill Nickerson also discussed Condition-Based Maintenance in a Maintenance Technologies for Availability session.

Opportunities like the annual DoD Maintenance Conference provide organizations like ARL Penn State and NAVAIR with a chance to gain knowledge, disseminate, and interact with industry and service maintenance experts. Next year's DoD Maintenance Symposium & Exhibition will focus on maintenance management and process technologies that will enhance maintenance operations in the future. The event will be held in Charleston, South Carolina, Oct. 30th through Nov. 2nd.

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IN THIS QUARTERLY

Feature Article 3
Institute Notes 6
Calendar of Events 8

DIRECTOR'S CORNER

Good-bye

We are rapidly approaching the end of 1999 and wondering what the years 2000 and beyond have in store for us. This has been a very exciting year. In this issue of the iMAST newsletter, we are featuring our repair technology program, which is funded through the Navy Manufacturing and Technology (ManTech) Program Office. Our feature article on the Automated Paint Application, Containment, and Treatment System (APACTS) was written by Dr. Robert Keay, a senior research associate who has a great deal of experience in this field. Technology transfer, which is vital to the way we do business with the Navy and Marine Corps, is being accomplished through a commercial products contract with Oceaneering, Inc.

In order to enhance our technology transfer initiatives, we have increased our participation in conferences and expositions. Since September, we have participated in seven events focusing on shipbuilding, Marine Corps requirements, electro-optics, gear technology, and repair technology. As we finish up the year, we are preparing for the annual Defense Manufacturing Conference (DMC), which will be held in Miami, Florida. By the time you receive this newsletter, the conference will have been completed. But as I write this now, we are preparing a thirty-foot-wide display—our largest ever—to showcase our efforts to DoD and manufacturing technologists. Twenty feet of our display will be devoted to iMAST, with the additional ten feet addressing electro-optics.

Now comes the difficult part. I came to Penn State in 1984 with a plan to spend fifteen years here before retiring and heading back to my home state of South Carolina. My fifteen years are up in December of this year. My wife and I built a retirement home three years ago on property we purchased during 1980. It is located on Lake Keowee in the foothills of western South Carolina. While I plan to retire from Penn State, I do not plan to quit working. I have accepted a position with Clemson University, my alma mater, and will be addressing manufacturing issues there. It is my hope to continue to interact with many of you on a continuing basis and to develop a continued relationship with Penn State. Manufacturing technology, you see, is in my blood.

My years of working with Navy ManTech have been challenging, fulfilling, and rewarding. It has been my fortune to associate with many great people who guard the foundation of this great country's strong defense industrial manufacturing base. Our industrial engineering capacity ranks second to none. It has bolstered our national defense and contributed to the country's prosperity. We need, however, to continue to challenge ourselves to stay on the leading edge. Programs like iMAST will chart our national course while providing a path to preserve the potential of our future.

In the meantime, I hope that you all enjoy the holiday season and have a happy and prosperous year 2000.

Henry Watson

Focus on Environmentally Friendly Technologies

Automated Paint Application, Containment, and treatment System (APACTS) for Dry Dock Hull Coating Operations

by Robert E. Keay, Ph.D.

Shipyards within the United States Department of the Navy and the commercial sector have placed a major emphasis on developing more efficient operations having minimal adverse impacts on the surrounding environment. Thirty-five shipyards are considered major sources of hazardous air pollutants (HAP), and compliance with the latest NPDES discharge limits for copper is unlikely without the implementation of paint overspray control procedures.[1]

The iMAST Center of Excellence (COE) at the Applied Research Laboratory at Penn State (ARL) supports the U.S. Navy in its efforts to improve shipyard operations and address the indicated environmental issues. Over the past three years, the Environmental Technology Group within iMAST, along with faculty at Penn State, have studied various issues of paint application (transfer efficiency), paint overspray, and overspray capture and treatment as related to shipyard dry-dock hull painting operations. Such efforts have been supported by the Naval Surface Warfare Center at Carderock (NSWC-CD) and the Navy ManTech program.

Background

An automated paint application, containment, and treatment system, called APACTS, was a vision born at Carderock (NSWC-CD) in early 1997.[2] The concept is to develop a mobile, semi-automated, robotics-controlled (but with real-time operator input) platform that could simultaneously apply paint and capture overspray during dry-dock ship hull coating operations as represented in Figure 1. Surveys indicated that there were no patented or commercially available, mobile and "at-the-nozzle" overspray collection systems then in existence.[1]

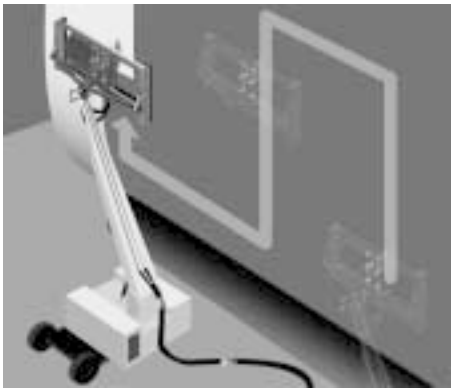

Figure 1. Conceptual representation of APACTS (treatment stage is not shown).

The captured overspray is directed to an appropriate physical, possibly chemical, treatment system (not shown), which must also be mobile in design. Envisioned advantages would be faster and more uniform rates of paint application with reduced manpower and improved compliance with growing regulations for the control of air and water pollutants.

Overspray and Capture

The initial APACTS program effort began within the Gas Dynamics Laboratory (GDLab), part of the Mechanical Engineering Department at Penn State under the direction of Professor Gary Settles, and with the support of Mr. Charles Tricou of the Environmental Technology Group within iMAST.[3,4] An understanding of the phenomenon and mechanism of "paint overspray" for airless paint spray systems was initiated. Using laser-based flow field visualization techniques as shown in Figure 2, the GDLab confirmed, for airless spray painting, earlier observations that paint overspray was caused when small paint particles having insufficient mass to reach the target, were carried away by the entrained airflow.[5,6,7]

Figure 2. Flow visualization of overspray.

In other words during the course of atomizing and applying paint

PROFILE

Robert E. Keay is a research engineer and head of the Environmental Technology Group in ARL Penn State's Manufacturing Systems Division. Dr. Keay received a B.S. in Chemistry from Rider College and a Ph.D. in Organic Chemistry from The Pennsylvania State University.

Dr. Keay is currently involved in research in advanced oxidation systems for air and water environmental pollutant control for VOCs, HAPs, and similarly related materials. Dr. Keay's academic expertise is in physical organic chemistry with emphasis on organic oxidation mechanisms involving "activated oxygen species" and ozone chemistry. He can be reached at (814) 865-7222, or by e-mail at rek10@psu.edu.

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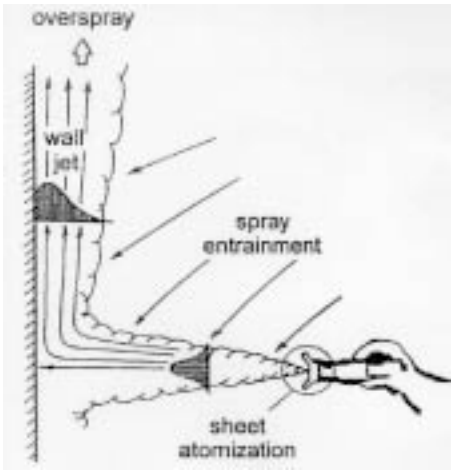

Figure 3. Schematic of overspray generation.

in airless paint systems, considerable air is entrained, creating a collateral stream of air initially directed towards the target surface. However, as represented in Figure 3, upon encountering the target surface, such air is directed at a 90-degree angle outwards from the plane of the paint spray fan and now travels as a wall jet parallel to the target surface. Overspray occurs when paint particles that are too small and that have insufficient inertia to cross the streamlines and to contact the target are carried outwards, away, and parallel to the target, ending in a fine-particle paint dispersion free to migrate elsewhere. It has been estimated that paint particles of 50 microns or less are most likely responsible for overspray.[8] This latest effort within the GDL clearly indicates once again that overspray was not a splash-back phenomena as classically envisioned.

With the knowledge of the origin of overspray, the next phase of the project dealt with modeling the overspray process and designing an effective capture device for overspray under hull painting conditions. The successful efforts within the GDLab resulted in the development of a 2-D model and a 3-D laboratory prototype demonstration of a shroud-like enclosure surrounding the paint spraygun.[7,9,10] See Figures 4 and 5. The principle of this device takes advantage of the natural

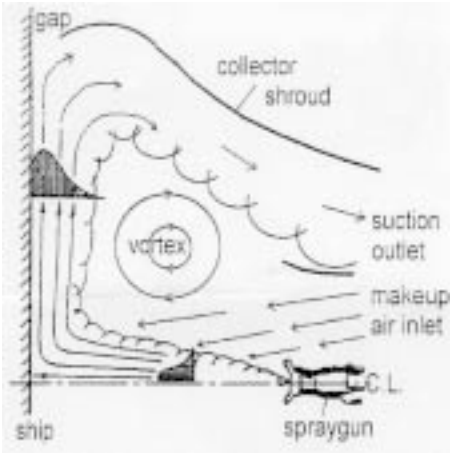

Figure 4. Overspray collector shroud concept.

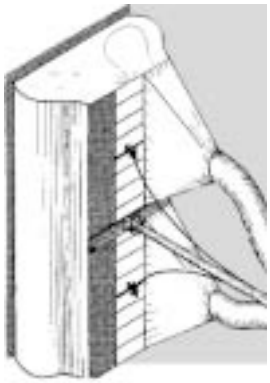

Figure 5. 3-D representation of overspray collector shroud (left side removed for clarity).

vorticity generated by the impingement of the spray to separate the overspray-containing wall jet from the wall and direct it toward a suction outlet.[9,11]

The laboratory prototype and minor modifications thereto are further tested under various hull painting conditions and capture parameters and achieved 90+% overspray capture with a standoff distance of up to 4 inches as shown in Figures 6 and 7 (footnote:12). A key technical issue, the buildup of captured wet paint particles was monitored and shown to occur only within the shroud itself and the first few feet of transfer line. Design considerations will address easy clean out of these system parts.

Treatment Options

Working with NSWC-CD, a set of criteria defining likely pollutant loads arising from the effective capture of paint overspray was developed. Based on immediately released VOC/HAP loads,

Figure 6. Close-up view of 3-D prototype collection shroud and capture duct lines.

Figure 7. 3-D prototype collection shroud and capture duct lines.

various particulate loads, volumetric flows, daily operating schedules, etc., various downstream treatment options were compared by Dr. Bradley Striebig of the Environmental Technology Group within iMAST.[13]

Various treatment options and combinations were evaluated and a relative ranking of these treatment possibilities when effectiveness, practicality, and costs were considered is shown in Table 1.[14]

In both an operational and economic sense, dry filtration is totally inadequate to handle the particulate load of dry paint particles reaching the treatment stage. While the many options for chemical treatment and destruction (carbon adsorption excluded) are all technically viable, these evaluations showed that a bio-oxidation approach had the best overall suitability based on

Table 1. APACTS Treatment Options Overview.

Suitability Ranking	Particulate Control	Chemical Control	Particulate and Chemical Control
Highest	Wet Filtration/venturi	Biological Oxidation	Wet Filtration/venturi Biological Oxidation
		Catalytic Oxidation	
		Advanced Oxidation	
		Thermal Incineration	
Lowest	Dry filtration	Carbon Adsorption	Dry filtration and Carbon Adsorption

the system limits on size and need for mobility. Carbon adsorption has high costs and off-site disposal issues. A wet filtration/venturi vacuum system feeding a novel bio-filter design is considered an optimum compromise for the APACTS project (see Figure 8).

Robotics and Control

The control system design and prototype mechanics are being developed at the National Institute of Standards and Technology (NIST) under the direction of Mr. Richard Norcross.[15]

The paint applicator and capture shroud control concept envisioned will employ two serially linked manipulators under some common supervisory control. This approach will provide five degrees of freedom when the large manipulator is stationary; the ultimate trajectory of the paint application and capture shroud will be based on real-time sensor feedback (see Figure 9). The respectively mated systems are termed a "macro and micro" control strategy. The current rates of motion trajectories for the APACTS concept are targeting hull painting application and overspray capture rates of approximately 2,500 ft^2 per hour (see Figure 10).

Figure 8.* Conceptual design of an APACTS treatment system.

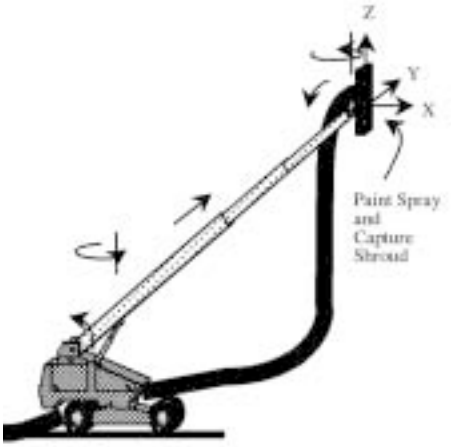

Figure 9. APACTS manipulator concept with five degrees of freedom.

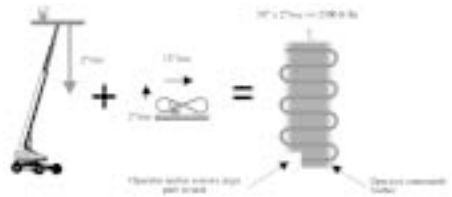

Figure 10.* Paint application concept and spray and capture shroud motion.

Technology Transition and Full Scale Prototype

Most recently, Oceaneering, Inc., based in Houston, Texas, was awarded a contract to transition the aforementioned technology, and to design and deliver a full-scale working APACTS prototype. Demonstration and validation of APACTS is currently scheduled for 2002 with shipyard implementation shortly thereafter.

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2. For more information contact Mr. William Thomas, NSWC-CD, Code 632, at (301) 227-5258 or Mr. Jerald Bohlander, NSWC-CD, Code 641, at (301) 227-4498.
3. The Gas Dynamics Laboratory and Professor Gary Settles, Department of Mechanical Engineering, Penn State University, can be reached at (814)-863-1504.
4. Mr. Charlie Tricou of the Environmental Technology Group, ARL Penn State, can be reached at (814) 863-4459.
5. Hicks and Senser, Journal of Fluids Engineering, Vol 117, No. 4 (1995), p. 717ff.
6. Settles, G. S., Proceedings of the 10th Annual Conference on Liquid Atomization and Spray Systems, Ottawa, Canada, May 18-21, 1997, pp 145-149.
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11. Settles, G. S., et. al., "Visualization and Collection of Overspray from Airless Spray Painting", Proceedings of the 8th International Symposium on Flow Visualization, Sorrento, Italy, Sept. 1-4, 1998, Paper No. 138.
12. Tricou, C. S., Validation Trials - NSWC Overspray Collector, ARL Penn State, July 1999.
13. Dr. Bradley Striebig of the Environmental Technology Group, ARL Penn State, can be reached at (814) 863-9911.
14. Striebig, B. A., et. al., "Conceptual Design for the Treatment of Paint Overspray with an Automated Paint Application, Containment and Treatment System," Technical Report 99-046, The Applied Research Laboratory Penn State, April 15, 1999.
15. Mr. Richard Norcross of the National Institute of Standards and Technology can be reached at (301) 975-3440.

**Full-size figures 8 and 10 available upon request.*

Commander Wendy Lawrence (left), ARL's Mr. Mike Yukish (center), and Mr. Ben Gimeno (seated) pause for a photo during a SBD computer software demonstration. Commander Lawrence is a three-time shuttle astronaut currently on assignment with the NRO.

Dr. Joe Hoeg explains intricacies of a LASCOR panel specimen to Admiral Dyer and members of his staff.

iMAST's Lewis Watt (right) shares the spotlight with exhibit visitor Scott Story. Mr. Story is a program engineer with the Advanced Amphibious Assault Vehicle (AAAV) program office in Woodbridge, Virgina. Mr. Story also serves as a technical advisor to iMAST for many of its Navy ManTech projects related to the AAAV.

ARL's Lewis Watt discusses a laser welding process with Mr. Dale Moore.

NRO Takes Look at SBD

Principal staff from the National Reconnaissance Office (NRO) recently visited the Applied Research Laboratory to discuss Simulation-Based Design (SBD) efforts ongoing within ARL's iMAST program. Mr. Eric Sundberg, Commander Wendy Lawrence, USN, and Mr. Ben Gimeno met with iMAST staff members to investigate new paradigms to assist them in satellite design efforts. NRO's exploratory visit was part of their Director's Innovation Initiative (DII). ARL has been applying SBD techniques to various ground and air weapon system platforms in concert with current undersea weapons development efforts.

The NRO designs, builds, and operates the nation's reconnaissance satellites. NRO products, provided to an expanding list of customers like the Central Intelligence Agency and the Department of Defense, can warn of potential trouble spots around the world, help plan military operations, and monitor the environment.

SBD is a process for rapidly exploring a design space to evaluate the cost, performance, and design characteristics of multiple alternatives in the form of virtual systems and process prototypes. It relies on an object-based information model-controlled software architecture to integrate heterogeneous, geographically distributed computer systems, models, and databases to synthesize and evaluate the alternatives in a "fly before buy" process. For more information about ARL's SBD program, contact Mr. Mike Yukish at (814) 863-7143 or by e-mail at: <may106@psu.edu>.

Assistant Commander, NAVAIR R&E Visits iMAST

RAdm Joseph Dyer, USN, Assistant Commander for Research and Engineering at the Naval Air Systems Command (NAVAIR), along with key staff members, recently visited iMAST as part of an ARL Penn State capabilities review initiative.

NAVAIR, in partnership with industry and academia, serves the nation and the Navy by developing, acquiring, and supporting naval aeronautical and related technology systems with which the operating forces, in support of the Unified Commanders and our allies, can train, fight, and win. NAVAIR is headquartered at the Naval Air Station in Patuxent River, Maryland. For more information about the NAVAIR-ARL Penn State team, contact Dr. Joe Hoeg at (301) 475-9380 or by e-mail at: <hoeg@erols.com>.

Modern Day Marine Military Exposition

iMAST participated once again in the annual Marine Corps League Modern Day Marine Military Exposition held at Quantico, Virginia. The expo provided an excellent opportunity to meet with program managers, engineers, and Marine Corps leaders throughout the Marine Corps Systems Command and Headquarters, U.S. Marine Corps. The expo provides an excellent opportunity to showcase ARL's capabilities before the Corps' senior leadership and systems engineers. iMAST is already gearing up for next year's expo, which will be held at Quantico, Sept. 19–21, 2000.

Director, Becker Materials Research Laboratory, NAVAIR Visits iMAST

Mr. Dale Moore, Director of the Materials Research Laboratory at the Naval Air Systems Command at Patuxent River, Maryland, visited ARL recently to receive a review and update on current efforts related to NAVAIR activities. iMAST currently has a number of Navy ManTech efforts ongoing in support of NAVAIR. Mr. Moore's visit dovetailed with earlier noted visits by Rear Admiral Joseph Dyer and Colonel Nolan Schmidt. ARL's iMAST program is currently addressing NAVAIR issues relative to aviation depot repair issues, V-22, JSF, and aircraft carrier catapult systems.

ARL's Bob Johnson demonstrates principles of acoustic refrigeration to Colonel Schmidt.

ARL research assistant Ted Reutzel (right) discusses strength and weight virtues of LASCOR paneling with Colonel Schmidt.

V-22 Program Manager Visits iMAST

Colonel Nolan Schmidt, USMC, PMA-275 program manager for the V-22 Osprey tiltrotor aircraft at NAVAIR, recently visited iMAST to specifically review progress on iMAST's ausform finishing effort. PMA-275 is the stakeholder for the gear ausform finishing program, which is addressing advanced manufacturing processes that will enhance precision gear performance. Colonel Schmidt is also evaluating characteristics of LASCOR paneling for strong, lightweight, augmented floor loading support in the aircraft. Because of his interest in alternative cabin cooling techniques, Colonel Schmidt also requested a briefing on ARL's remote cooling thermoacoustic refrigeration efforts. For more information on the efforts noted above, please contact the following individuals:

- Ausform finishing of gears and bearings
  Dr. Nagesh Sonti, (814) 865-6283, <nxs7@psu.edu>
- LASCOR paneling
  Mr. Ted Reutzel, (814) 863-9891, <ewr101@psu.edu>
- Acoustic Refrigeration
  Mr. Robert Johnson, (814) 863-7140, <raj1@psu.edu>

The V-22 Osprey is the first aircraft designed from the ground up to meet the needs of all four U.S. armed services. The aircraft can transport Marine Corps assault troops and cargo using its medium lift and vertical takeoff and landing capabilities. It meets U.S. Navy requirements for combat search and rescue, fleet logistics support, and special warfare support.

The V-22 is a tiltrotor aircraft, which takes off and lands like a helicopter, but, once airborne, its engine nacelles can be rotated to convert the aircraft to a turboprop airplane capable of high-speed, high-altitude flight. It can carry 24 combat troops, or up to 20,000 pounds of internal or external cargo, at twice the speed of a helicopter.

The aircraft is a joint venture by Bell Helicopter Textron and Boeing. Boeing is responsible for the fuselage and all subsystems, digital avionics, and fly-by-wire flight-control systems. Boeing partner Bell Helicopter Textron, Inc., is responsible for the wing, transmissions, empennage, rotor systems, and engine installation.

V-22

CALENDAR OF EVENTS

19–21 Jan	AHS Vertical Lift Design Conference	San Francisco, CA
29 Jan–1 Feb	NDIA Tactical Wheeled Vehicles Conference	Monterey, CA
14–18 Feb	UCLA Airframe Design and Repairs	Los Angeles, CA
27–30 Mar	U.S. Army Ground Vehicle Survivability Symposium	Monterey, CA
5–6 Apr	M2AB Advisory Meeting	State College, PA
18–20 Apr	Navy League Expo	Washington, D.C.
2–4 May	American Helicopter Society Forum 56	Virginia Beach, VA
17–19 May	JDMTP Sustainment Working Group	State College, PA
19–21 Sep	Modern Day Marine Expo	Quantico, VA
29 Oct–1 Nov	AHS Powered Lift Conference	Arlington, VA
30 Oct–2 Nov	4th Annual NDIA DoD Maintenance Conference	Columbia, SC
26–30 Nov	Defense Manufacturing Conference 2000	Tampa, FL

Quotable

"Everything that can be invented has been invented." — *Charles H. Duell, Commissioner, U.S. Patent Office, 1899*

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